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**ES** ENGINEERING-SCIENCE

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November 8, 1991

Mr. Jim Williams
Department of the Air Force
Center for Environmental Excellence
Environmental Restoration Division (ESR)
Building 624 West
Brooks AFB, Texas 78235-5000

Subject: Letter Report for the Bioventing Diagnostic Work and Proposed Conceptual Design for the 7th Street Services Station, Eglin AFB, Florida

Dear Mr. Williams

Engineering-Science (ES) has completed diagnostic tests to evaluate the use of in-situ bioventing remediation technology to support remediation effort at the 7th Street Gasoline Station, Eglin AFB. This letter report summarizes the results of the evaluation and provides recommendations for full scale remediation with emphasis on applicable conceptual design for the site.

The report is organized as follows

- Introduction
- Site Description and History
- Diagnostic Tests
  - Air Permeability Tests
  - Soil Gas Analysis
  - In-Situ Respiration Test
- Recommendation for Full Scale Remediation

554-7100

## INTRODUCTION

On October 7 and 8, 1991, representatives of the Air Force Center for Environmental Excellence and Engineering-Science, Inc. conducted a series of diagnostic tests to determine the feasibility of using in-situ bioventing to remediate a fuel spill at the 7th Street Gasoline Station on Eglin AFB, Florida. Three diagnostic tests were attempted during this 24-hour site visit. Two of the tests, an air

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permeability and initial soil gas analysis were completed. A third test to estimate in situ respiration rates was unsuccessful because the test extraction well was not located in fuel contaminated soils. A brief summary of the results of these tests and a recommended approach for full-scale remediation is included in this letter report.

**SITE DESCRIPTION AND HISTORY**

The 7th Street BX station is located near the intersection of 7th Street and Eglin Boulevard on Eglin Main Base. Geologically, the site is underlain by sands and silty sands, which overlie the Pensacola clay at an approximate depth of 150 feet. Groundwater occurs in the shallow sands between 5 and 7 feet below ground surface (bgs). The apparent generalized direction of groundwater flow is toward the south-southeast, as indicated by historic groundwater levels in site monitoring wells (see Figure 1). Water levels in deep wells (screened 45-50 ft bgs) indicate there is also a downward vertical component of groundwater flow near the water table. The results of a pumping test conducted during the start-up of the recovery system indicate that the average transmissivity within the shallow sands is approximately 13,000 gallons per day per foot (gpd/ft).

The environmental investigation conducted by Geraghty and Miller (G&M) in 1985 indicated the presence of volatile and semivolatile organic compounds in groundwater at the 7th Street site.

The G&M data indicate there may have been two nearly separate plumes of contamination near the 7th Street Gas Station: one plume immediately beneath the gas station and a second plume located downgradient from the station and adjacent to an automobile maintenance building. The chlorinated compounds were only found in the second plume. The lateral extent of the second plume was not well defined. G&M speculated that there may have been a separate source of groundwater contamination associated with the maintenance building.

A groundwater recovery and treatment system was constructed at the site in 1987 to remove floating and dissolved petroleum hydrocarbons from the groundwater. Quarterly sampling data indicate that BTEX concentrations in site monitoring wells have remained consistently high, though there is some indication that the contamination is migrating in a downgradient direction. Air stripper influent sample collected during 1988 and 1989 by ORNL personnel did indicate the presence of other chlorinated hydrocarbons at low concentrations (less than 1 $\mu g/L$).

Free fuel product has been measured at the site at various times over the past 5 years. G&M detected product ranging in thickness from 0.5 to 1.5 inches. Subsequent investigations by $CH_2M$ Hill and others have not detected any free

product at the site. However, ES detected free product ranging in thickness up to 0.47 feet (GW-1) during November 1990. No soil sampling or analysis has been completed on the site.

**BIOVENTING DIAGNOSTIC TESTS**

**Air Permeability Tests**

Three air permeability tests were conducted using existing monitoring wells MW-1, MW-8, and MW-10. Due to high water table conditions at the site, only MW-1 had over one foot of screen above the water table. Air permeability tests at MW-8 and MW-10 were performed by blowing air into those wells under a pressure of 50 inches of water. Although the groundwater depression was not measured, this pressure appears to have opened a foot or less of screened interval to air flow which was sufficient to pressurize the surrounding soil for the permeability tests.

Air permeability tests were performed by using a one-horsepower DR 404 Rotron® blower to inject up to 80 scfm of air into the shallow soils. At MW-1 a flow rate of 80 scfm was achieved at a steady-state pressure of 22″ $H_2O$. A 3/4 inch stainless-steel soil gas probe and Magnehelic™ pressure gauge were used to determine the steady-state soil pressures and estimate the air injection radius of influence around MW-1. Figure 2 illustrates the steady-state pressure profile achieved after only 15 minutes of air injection.

Because MW-1 is located in a sandy area with no surface barrier, the air injected at this well moved rapidly outward and upward. Under these conditions the radius of influence was estimated to be approximately 20 feet and the air permeability approximately 160 darcys. Air permeability was estimated using the equation:

$$K = \frac{Q\mu}{H\pi P_{atm} \dfrac{[1 - (P_w/P_{atm})^2]}{l_n R_w/R_1}}$$

A more complete description of this equation and the assumptions used in this calculation are provided in the attached calculation sheets.

Air injection tests were completed in MW-8 and MW-10 to determine the soil air permeability and radius of influence beneath the asphalt and concrete at the gasoline station. The DR 404 blower was connected to MW-8 and air injected at a rate of approximately 40 scfm at a pressure of 50″ of $H_2O$. Soil pressure influence was monitored by driving a soil gas probe approximately 4 feet deep in the soil at a point 40 feet east of MW-8 and within one foot of the edge of the asphalt surface.

In a separate test, the blower was connected to MW-10 and 40 scfm of air injected. The pressure influence was then measured using a Magnehelic™ pressure gauge attached to the soil gas probe located 40 feet north of MW-10. Figure 3 illustrates the increase in pressure vs. the natural log of time for the MW-8 and MW-10 air injections. Soil air permeability was estimated using the equation:

$$K = \frac{R^2 \eta \mu}{4 - \text{Patm} \left[ e^{(\beta/A + .5772)} \right]}$$

A more complete description of this equation and the assumptions used in the calculations are provided in the attached calculation sheets. Using this estimation method, air permeability beneath the asphalt ranged between 20 darcy on the north end of the spill site to 433 darcy at the south end of the spill site. Soil air permeabilities of 10 to 500 darcy are common values for medium and coarse sands (Johnson, 1990). Lower permeabilities near the north edge of the asphalt drive could be the result of the additional moisture observed in soils clinging to the extracted soil gas probe.

**Soil Gas Analysis**

MW-1 was selected for soil gas extraction and analysis because it was the only monitoring well near the fuel spill that had open screen above the water table. A 1 scfm vacuum pump was used to purge MW-1 for 10 minutes and draw in soil gas for analysis. A GasTech Model 32520X gas analyzer was used to measure oxygen and carbon dioxide in the soil gas. No oxygen was detected in the soil gas. A carbon dioxide concentration of 14 percent was measured. This indicates that existing soil bacteria are consuming all available oxygen, and that contaminated soils beneath the asphalt paving are anaerobic. The addition of oxygen using a bioventing system will accelerate the natural biodegradation of the remaining fuel residuals.

**In-situ Respiration Test**

An in-situ respiration test was attempted using MW-1 first as an air injection point and then as a soil gas monitoring point. Fresh air was injected at a rate of 80 scfm for approximately 12 hours using the DR 404 Rotron® blower. After 12 hours of air injection the DR 404 Rotron® blower was removed form the well and the 1 scfm vacuum pump was used to purge the well and draw in surrounding soil gas. Oxygen levels were elevated to 21 percent after the air injection and the in-situ respiration test was initiated. At one hour intervals MW-1 was purged for one minute and air samples analyzed for oxygen and carbon dioxide. Figure 4 illustrates the oxygen consumption measured during the 266 minute test.

Oxygen consumption was very slow at MW-1 and it does not appear that soils near this well contained sufficient contamination to provide a hydrocarbon source for natural bacteria. It is also possible that the 12 hours of air injection forced hydrocarbon vapors away from MW-1 and removed the hydrocarbons which existed near the well prior to the air injection. Similar tests at a jet fuel site at Tyndall AFB yielded average oxygen consumption rates of .004%/min, or 1500-2000 mg of total petroleum hydrocarbons per kg of soil per year. Although rates could not be measured at Eglin AFB due to the lack of a vapor monitoring well in the fuel contaminated soil, it is reasonable to assume that Eglin AFB soils and bacterial populations will produce similar rates when enhanced by bioventing.

**RECOMMENDATIONS FOR FULL-SCALE REMEDIATION**

Full-scale remediation of the site can be achieved through a combination of free product recovery, groundwater depression and treatment using the existing air stripper, and in-situ bioventing to remove fuel contamination from soils beneath and adjacent to the asphalt pavement. ES recommends restoration of the free product recovery system to remove the final layer of fuels from the groundwater soil interface. The existing groundwater recovery system should be operated at the maximum capacity possible without jeopardizing air stripper efficiency. This will provide a maximum depression of the groundwater table and increase the ability of the bioventing system to circulate air through the capillary fringe and total contaminated soil profile.

Due to the danger of forcing hydrocarbon vapors up and into the BX Service Station, a vacuum system is recommended to draw fresh air away from the building and under asphalt areas affected by the fuel spill. Based on an estimated volume of contaminated soil of 150′ x 200′ x 5′ or 150,000 cu. ft., and an assumed air filled porosity of .20, one void volume of air equals 30,000 cu. ft. If one void volume per day is used as a minimum flow, a flow of 21 scfm will provide one air exchange per day. The proposed bioventing system will operate at a flow rate that is sufficient to influence the entire contaminated volume but slow enough to optimize oxygen delivery without creating excess volatile emissions. Based on the radius of influence measured during our testing, the blower should ~~be~~ capable of operating in a range of 30-50 scfm at a vacuum of 50″ $H_2O$. The DR 404 Rotron® blower is slightly oversized for this application, but does provide additional capacity for recirculation of vapor-laden air.

not explosion proof

The bioventing system will be designed to maximize the recirculation of vapor-laden air through site soils. Figure 5 illustrates a recommended conceptual design for this site. Two 3″ vapor extraction wells will draw oxygenated air into the site from all directions stimulating aerobic biodegradation. A dilution valve located on the vacuum side of the blower will be used to control flow rates and supply

additional oxygen to the system. For one option, control and reduce volatile organics in the extracted air stream and further enhance biodegradation of these volatiles, air removed from the soils could be reinjected along the north edge of the asphalt using a 50 ft injection trench. This location for the injection trench would set up an air recirculation pattern in the northern half of the asphalt area away from the service station (see Figure 6). Minimal air would escape to the atmosphere because the flow gradient would pull air beneath the asphalt for multiple passes through the soil. To improve air permeability in this area, ES recommends that this grass island not receive artificial watering. In a second option, extracted air would be injected into a long pile of soil which will act as a "biofilter" and remove additional volatile organics from the air stream prior to discharge. The pile would be constructed of fuel contaminated soil from another Eglin AFB site, covered with 20-mil plastic and air injected through a 3″ perforated pipe running down the center of the pile.

The objectives of this system will be to: 1) supply oxygen to contaminated soils; 2) reduce volatile emissions by recirculating extracted gases through in situ or above ground soil "biofilters"; and 3) create a flow gradient away from the existing service station to prevent vapor hazards.

If you have any questions on this document, please contact me.

Sincerely,

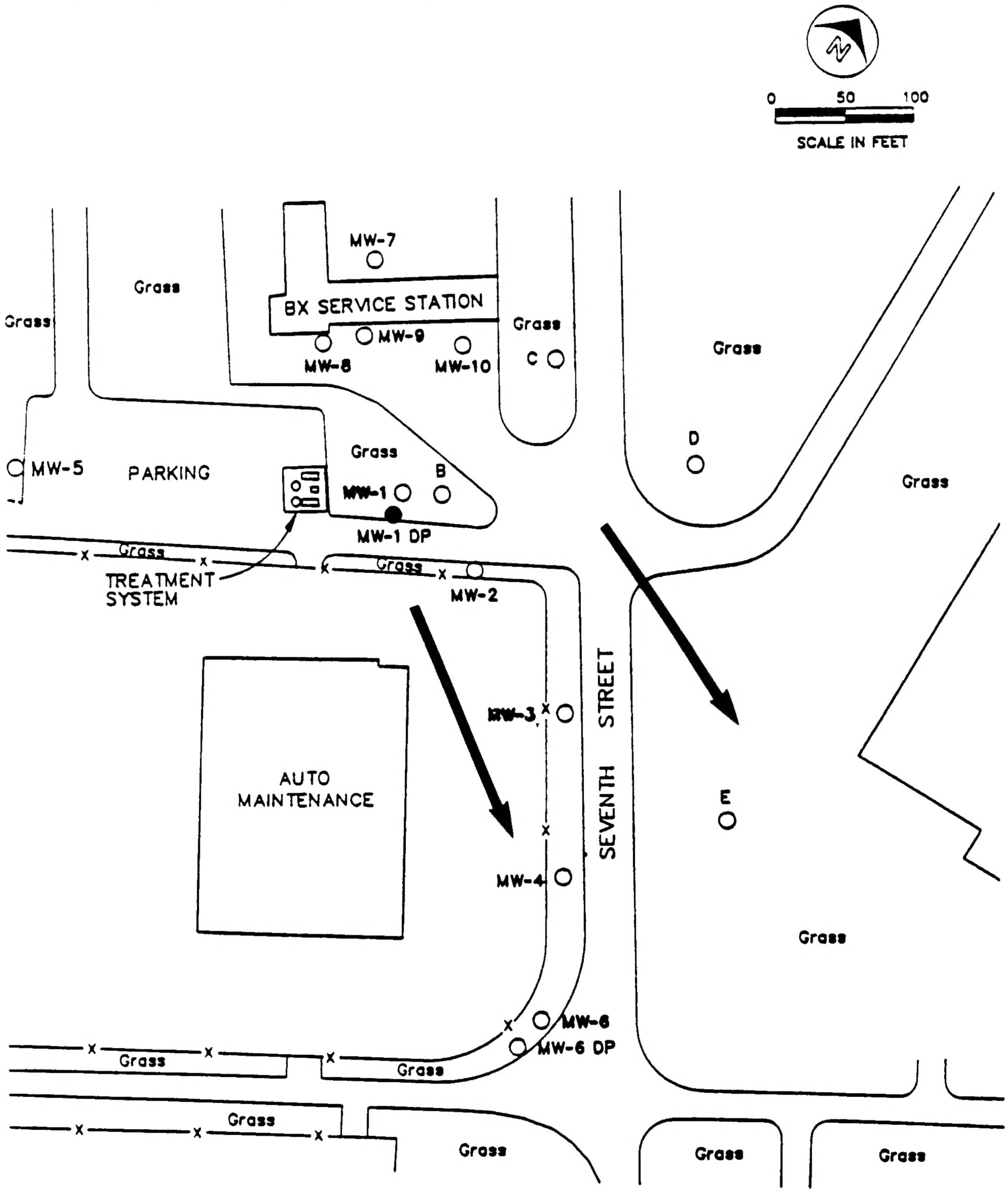
ENGINEERING-SCIENCE, INC.

Ola A. Awosika, P.G.
Project Manager

OAA:mahl
Attachments

cc: P. Means

EGLIN AFB
7TH STREET GAS STATION
MONITORING WELL LOCATIONS AND
GENERALIZED GROUNDWATER FLOW DIRECTIONS




LEGEND

○ SHALLOW MONITORING WELL (<10 FEET)

● DEEP MONITORING WELL (45-50 FEET)

GENERALIZED DIRECTION OF GROUNDWATER FLOW

SOURCE: CH2M HILL



ES ENGINEERING-SCIENCE

Figure 2

Pressure vs. Feet From MW-1

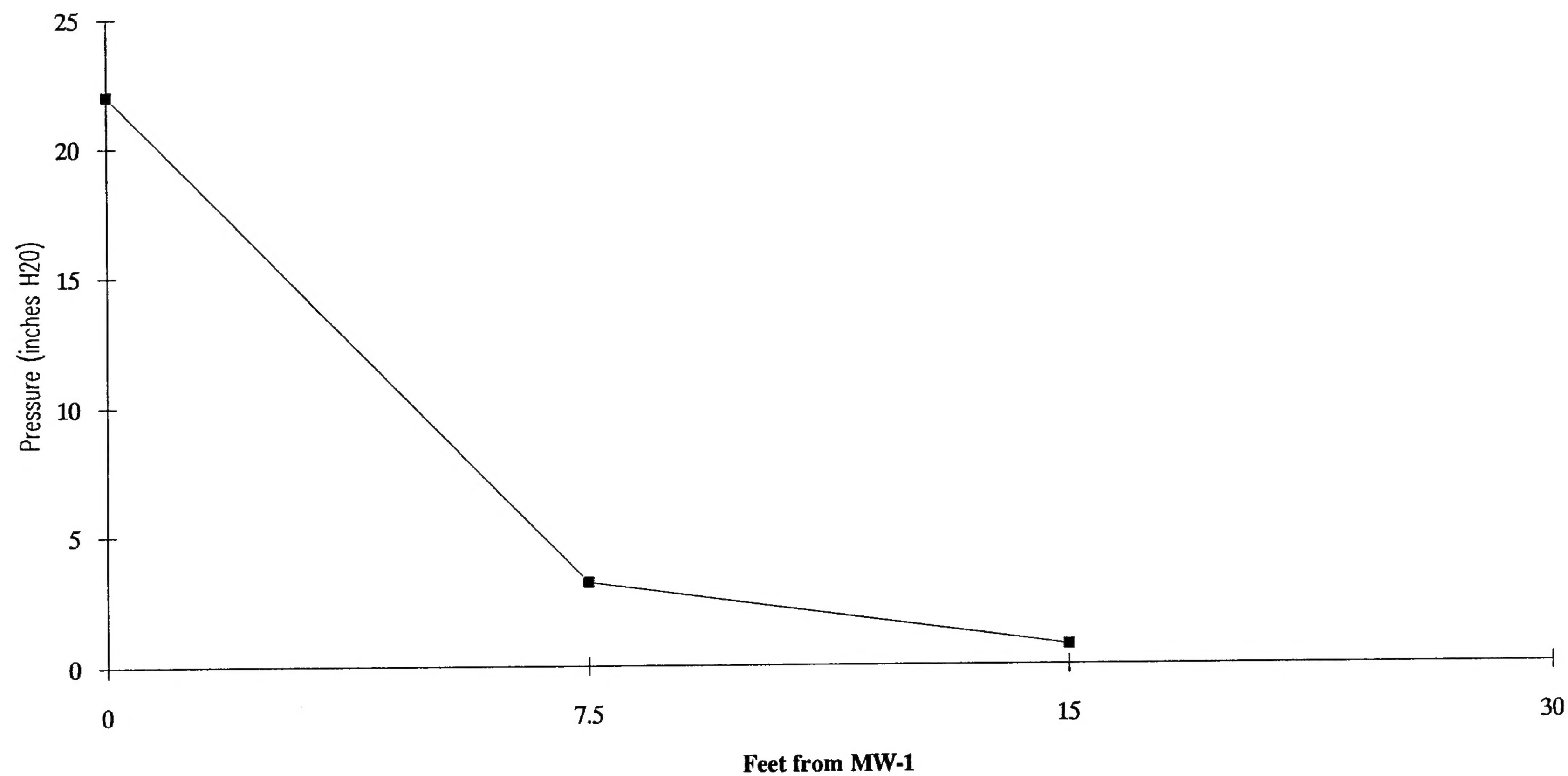


**Figure 3**
**Pressures vs. Ln(time)**

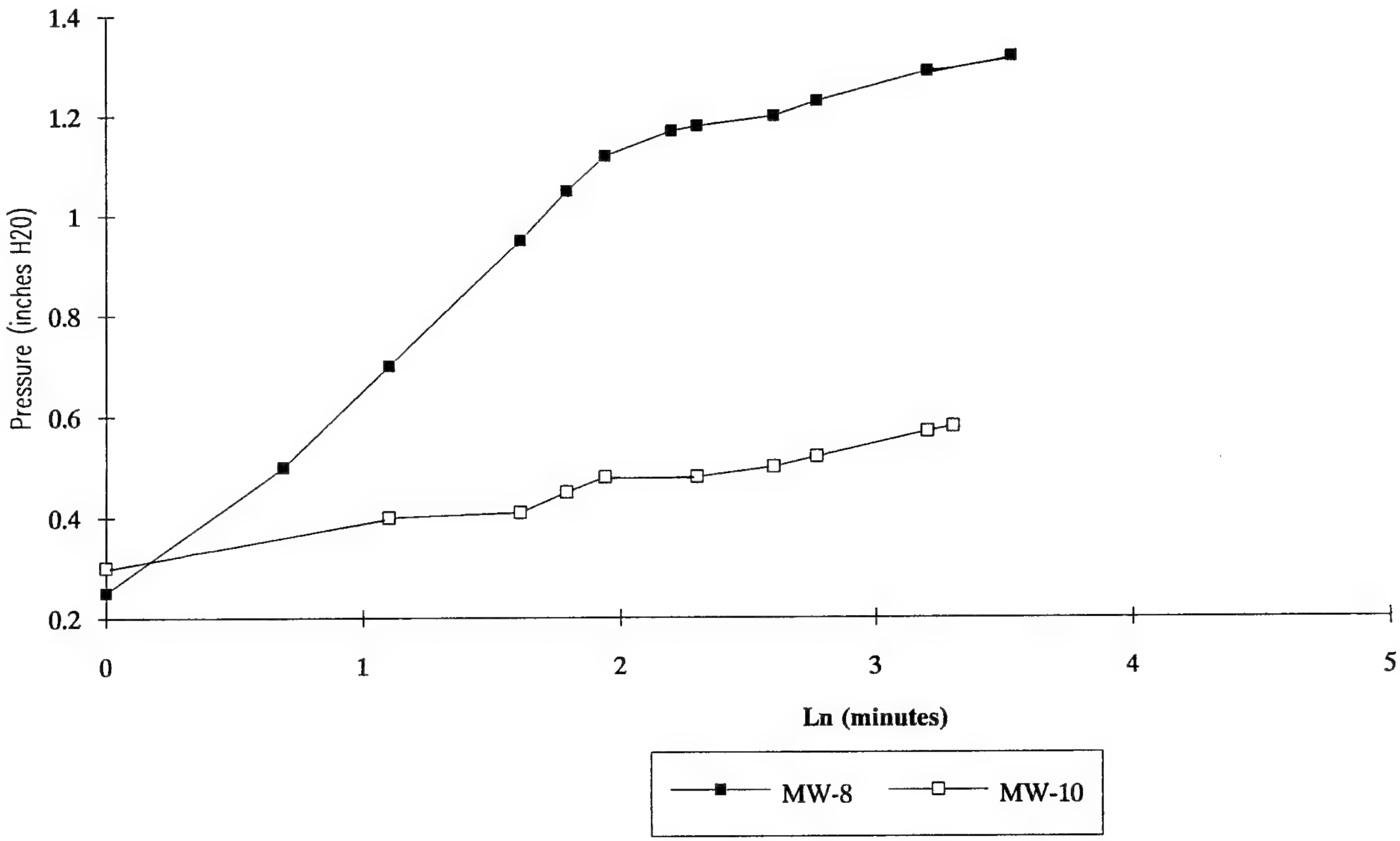


**Figure 4**

**Percent Oxygen vs. Time**

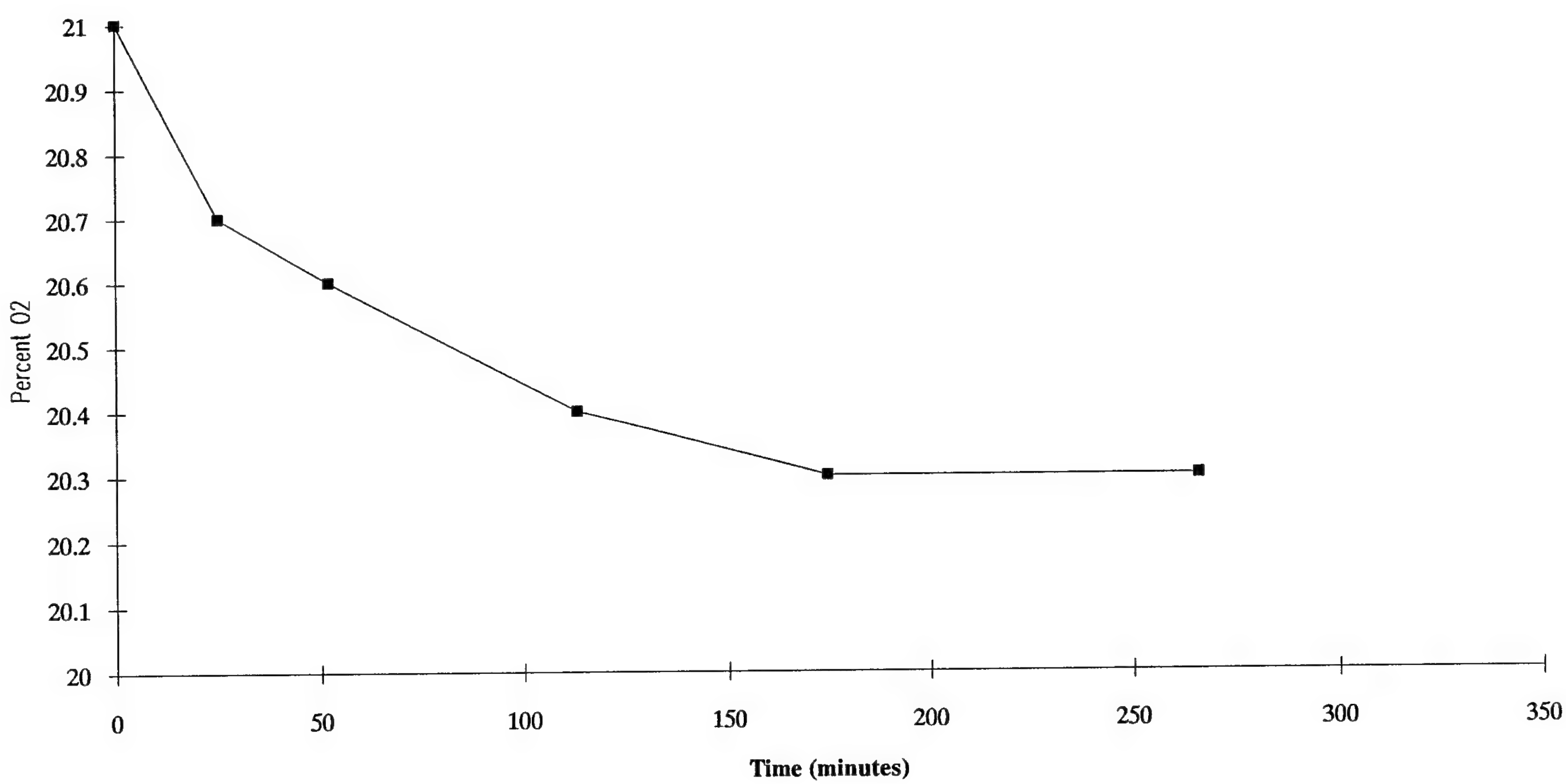


Figure 5

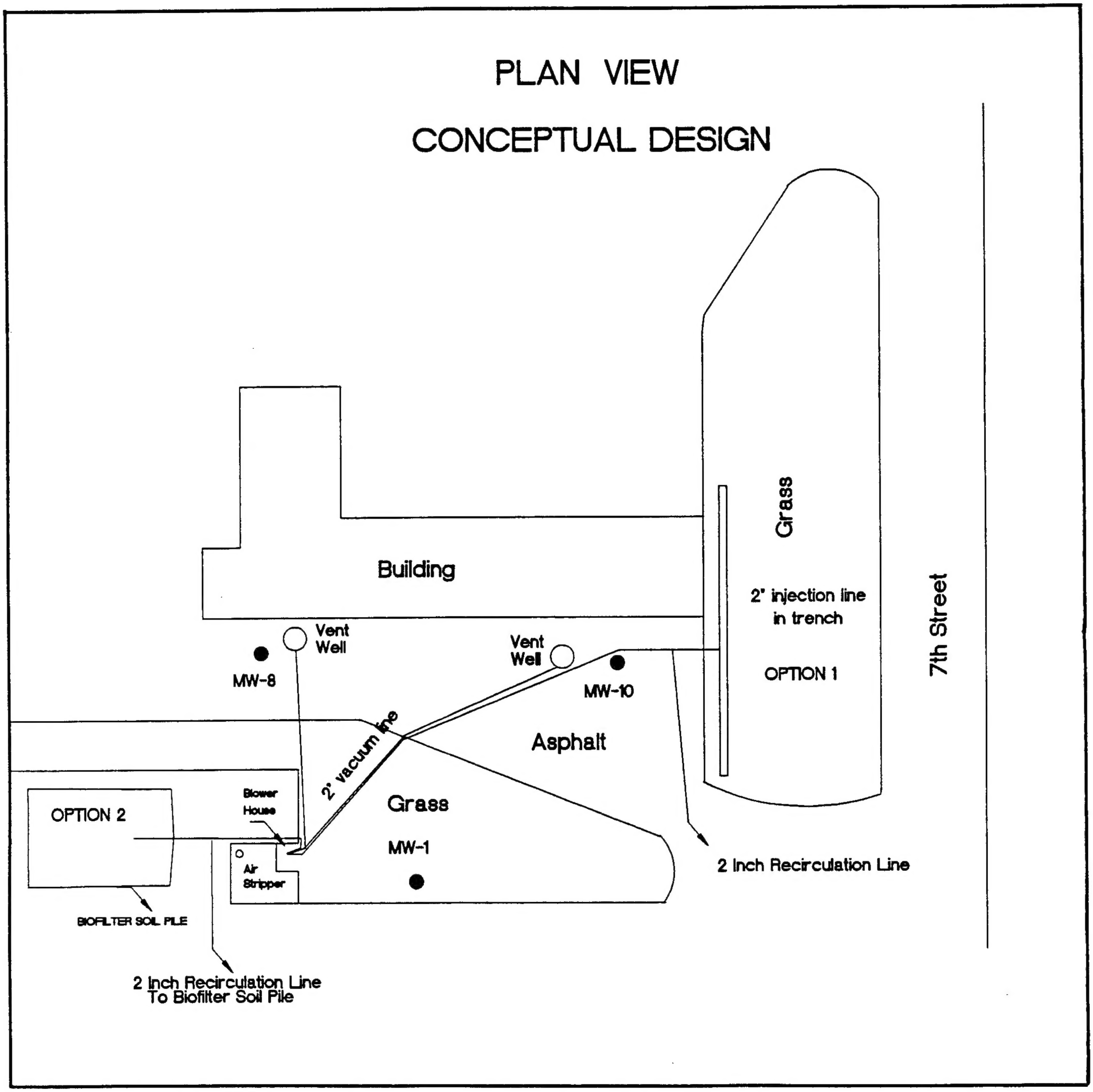
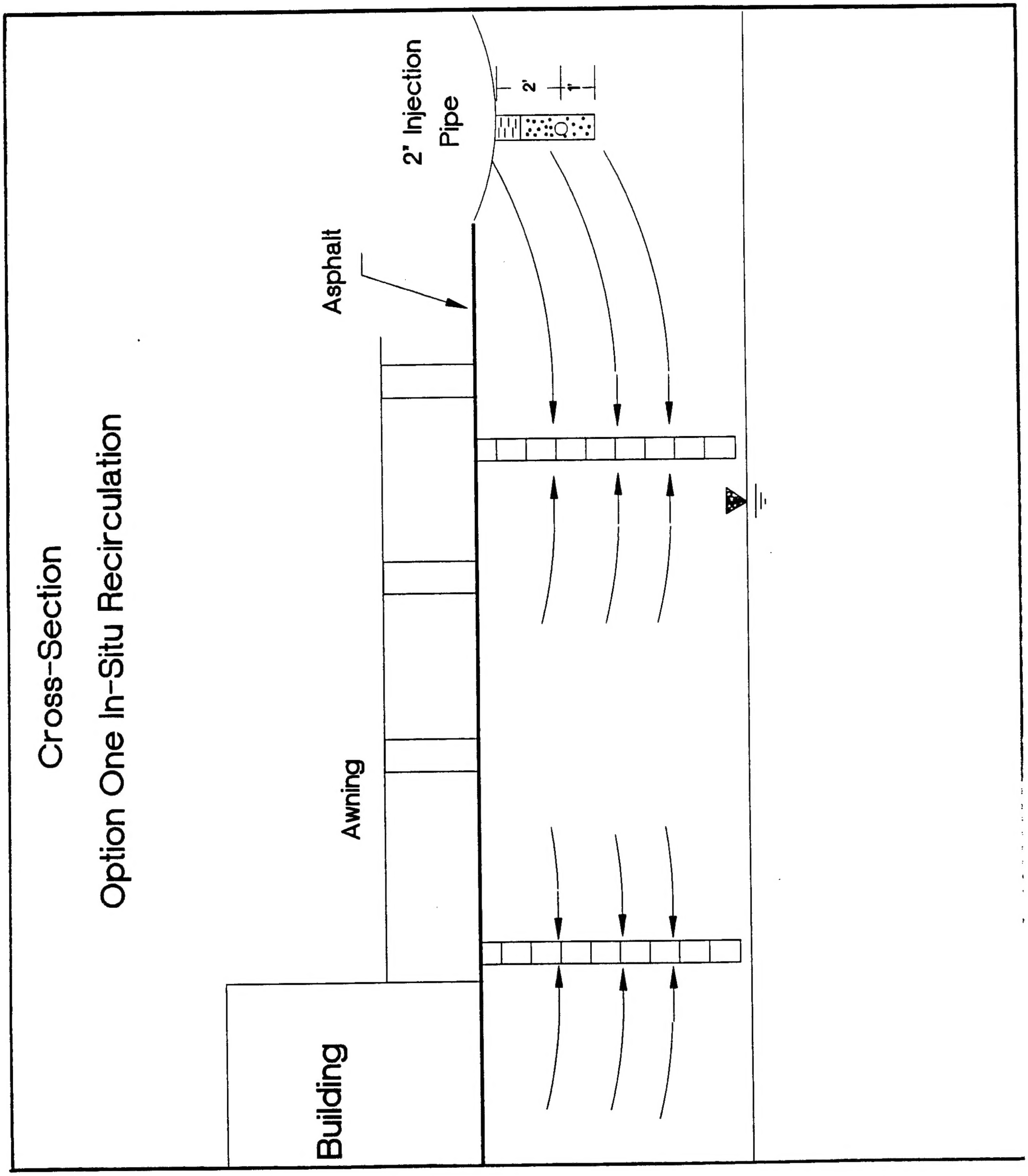

PLAN VIEW
CONCEPTUAL DESIGN
Grass
Building
2" injection line
in trench
OPTION 1
7th Street
Vent
Well
Vent
Well
MW-8
MW-10
2" vacuum line
Asphalt
Blower
House
OPTION 2
Grass
MW-1
Air
Stripper
2 Inch Recirculation Line
BIOFILTER SOIL PILE
2 Inch Recirculation Line
To Biofilter Soil Pile

Figure 6


Cross-Section
Option One In-Situ Recirculation
2" Injection
Pipe
2'
1'
Asphalt
Awning
Building

## CALCULATIONS

**Air Permeability* on MW-1**

$$K = \frac{Q\mu}{H\pi P_{atm} \dfrac{[1 - (P_w/P_{atm})^2]}{l_n R_w/R_1}}$$

Where:

$K$ = soil air permeability ($cm^2$)

$Q$ = flow rate at well ($cm^3/sec$): at 80 $ft^3/min$ x min/60 sec x 28,000 $cm^3/ft^3$ = $3.8 \times 10^4$ $cm^3/sec$

$\mu$ = viscosity of air ($1.8 \times 10^{-4}$ g/cm-sec)

$H$ = Screened interval (assume 2 ft or 61 cm)

$P_{atm}$ = absolute ambient pressure (use $1.01 \times 10^6$ $g/cm\text{-}sec^2$)

$P_w$ = absolute pressure at injection well ($g/cm\text{-}sec^2$)

$$= 22'' \ H_2O \times \frac{3.61 \times 10^{-2} \text{ psia}}{\text{in of } H_2O}$$

1 atm = 14.7 psia

14.7 + .79 = 15.49 psia

15.49 psia x ($6.9 \times 10^4$ $gm/cm\text{-}sec^2$)/psia = $1.07 \times 10^6$ $g/cm\text{-}sec^2$

$R_w$ = Radius of injected well (1″ = 2.54 cm)

$R_1$ = Radius of influence (based on pressure vs. distance profile) = 20 ft (610 cm)

Solving for K:

$$K = \frac{(3.8 \times 10^4 \ cm^3/sec) \times (1.8 \times 10^{-4} \ g/cm\text{-}sec)}{(61 \ cm)(3.14)(1.01 \times 10^6 \ g/cm - sec^2) \left[\dfrac{1 - (1.07/1.01)^2}{\ln 2.54/610}\right]} \quad \frac{-.1223}{-5.4813}$$

$= 1.58 \times 10^{-6}$ $cm^2$

$1.58 \times 10^{-6}$ $cm^2$ x 1 darcy/$9.87 \times 10^{-9}$ $cm^2$ = 160 darcy

* Equation from Johnson, D.C., et. al. 1990. A Practical Approach to the Design, Operation, and Monitoring of In-Situ Soil Venting Systems. GW Monitoring Review, Spring 1990.

**Air Permeability for MW-8 and MW-10**

$$K = \frac{R^2 \eta \mu}{4 - Patm \left[ e^{(\beta/A + .5772)} \right]}$$

Where:

R = distance from injection well to vapor monitoring probe (cm) 40 ft = 1220 cm

$\eta$ = air filled porosity (assume .20)

$\mu$ = viscosity of air $1.8 \times 10^{-4}$ g/cm sec

$P_{atm}$ = $1.01 \times 10^6$ g/cm - sec$^2$

ß = y intercept of pressure vs. ln time

A = slope of pressure vs. ln time

From Figure 2

For MW-8 injection Test:

A = .45 inches/ln min x $2.49 \times 10^3$ g/cm-s$^2$/ inch $H_2O$ = 1120 g/cm-s$^2$

ß = .25 inch $H_2O$ x $2.49 \times 10^3$ g/cm-s$^2$ = 622 g/cm-s$^2$

For MW-10 injection test:

A = .083 inch $H_2O$ x $2.49 \times 10^3$ g/cm-s$^2$ = 207 g/cm-s$^2$

ß = .30 inch $H_2O$ x $2.49 \times 10^3$ g/cm-s$^2$ = 747 g/cm-s$^2$

For MW-8 Test:

$$K = \frac{(1220 \text{ cm})^2 (.20)(1.8 \times 10^{-4})}{4(1.01 \times 10^6)\, e^{(622/1120 + .5772)}}$$

$$= 4.27 \times 10^{-6} \text{ cm}^2 \times 1 \text{ darcy}/9.87 \times 10^{-9} \text{ cm}^2 = \underline{433 \text{ darcy}}$$

For MW-10 Test:

$$K = \frac{(1220 \text{ cm})^2 (.20)(1.8 \times 10^{-4})}{4(1.01 \times 10^6)\, e^{(747/207 + .5772)}}$$

$$= 2.02 \times 10^{-7} \text{ cm}^2 \times 1 \text{ darcy}/9.87 \times 10^{-9} \text{ cm}^2 = \underline{20 \text{ darcy}}$$